

Multi-Dichroic-Layer Composite Thin-Film Polarizer Based on Azo Dyes

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Abstract

We present a multi-dichroic-layer composite thin-film polarizer to enhance the photostability of azo-dye-based polarizers. By layering LCP-M10 with azo dye films, the polarizer effectively prevents photodegradation, maintaining high absorbance and stability. Optical testing demonstrates the composite polarizer's superior performance, offering extended lifespan and enhanced reliability for high-performance display applications.

Author Keywords

Coatable Polarizer; Thin-Film Polarizer; Azo Dye.

1. Introduction

Polarizers are essential components in display devices, controlling the passage of light by selectively transmitting certain polarizations while blocking others¹. In liquid crystal displays (LCDs), polarizers play a critical role in setting the direction of light waves, which directly affects brightness, contrast, and overall image quality. Without polarizers, LCDs would not be able to modulate light effectively, making them a fundamental part of modern display systems².

There are two main types of polarizers: absorptive polarizers and reflective polarizers³. Absorptive polarizers use dichroic dyes to selectively absorb light polarized in one direction while allowing the perpendicular polarization to pass through. This absorption-based mechanism helps achieve high contrast ratios in displays. Reflective polarizers, on the other hand, work by reflecting unwanted polarizations while transmitting the necessary light, improving efficiency by recycling light within the system. Wire grid polarizers are a common example of this type, widely used in optical applications requiring high performance.

With the advancement of display technology, there is a growing demand for polarizers that not only offer superior optical performance but are also ultra-thin for seamless integration into display panels. Thin-film polarizers are particularly useful in in-cell LCD designs, where minimizing the thickness of optical components is crucial for achieving high-resolution, energy-efficient, and lightweight displays.

Absorptive polarizers that use azo dyes are attractive because azo dyes have a high dichroic ratio⁴. However, azo dye polarizers have a drawback. They tend to degrade when exposed to blue and ultraviolet (UV) light. This degradation is known as photodegradation, and it reduces the dichroic ratio and the overall performance of the polarizer over time. Photodegradation leads to a shorter lifespan for the polarizer, which is not acceptable for long-term use in displays.

To address this issue, researchers have explored various methods to enhance the photostability of azo dye polarizers. One approach is the incorporation of protective layers to shield the dye from direct exposure to harmful wavelengths. Another strategy involves modifying the dye's chemical structure to improve resistance to photodegradation.

In this study, we propose a multi-dichroic-layer composite thin-film polarizer. Figure 1 displays the schematic structure of this design. Herein, we add extra dichroic layers on top of the azo dye polarizer to protect it from the harmful effects of blue and UV light. By stacking several layers, the design helps to block and absorb harmful light before it reaches the sensitive azo dye layer. In this study, we use photo-aligned azo dye films (such as AD1 and AD12) as the primary polarizing layer. These films would change the alignment direction when exposed to blue or UV irradiation⁵⁻⁷. To counteract these changes, we add additional layers made from LCP-M10, a material that shows good photostability. This approach aims to maintain the optical properties of the polarizer for a longer time while keeping the structure thin and simple.

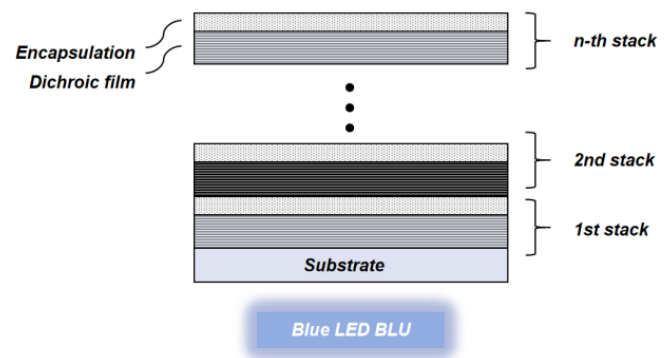


Fig. 1. Schematic of the multi-dichroic-layer composite thin-film polarizer.

2. Methodology and experiments

In our experiment, we began by preparing the photo-aligned azo dye films. These films, made from azo dye materials AD1 or AD12, serve as the primary polarizing layer. To improve photostability, we added extra layers to protect the azo dye film. We chose LCP-M10 for these additional layers because it resists photodegradation very well.

We prepared LCP-M10 films at two different concentrations. Here, the concentration refers to the percentage of M10 in the

LCP solution. We used concentrations of 1% and 3%. Next, we measured the absorbance of these films under two conditions. One was the S state, where the light is s-polarized (the electric field oscillates in one specific direction). The other was the P state, where the light is p-polarized (the electric field oscillates in a direction perpendicular to the S state). These measurements helped us understand how each film performs when light of different polarizations passes through.

Then, we designed three different multi-dichroic-layer structures. In each structure, the layers were stacked on top of one another. For each structure, we measured the absorbance of each layer and calculated the Dichroic Ratio (DR) for the films. The Dichroic Ratio is a key parameter that indicates how well a film can distinguish between the two polarizations. It is defined as:

$$\text{Dichroic Ratio} = \frac{A_p}{A_s}$$

Herein, A_p is the absorbance in the P state and A_s is the absorbance in the S state. The measured values of A_p , A_s , and the Dichroic Ratio for the three cases are shown in Figure 2.

(a)

Structure 1	A_p	A_s	DR
1% M10	0.2	0.04	5
AD1	3.6	0.02	180
3% M10	0.7	0.1	7

(b)

Structure 2	A_p	A_s	DR
1% M10	0.2	0.04	5
AD1	3.6	0.02	180
3% M10	0.7	0.1	7
3% M10	0.7	0.1	7

(c)

Structure 3	A_p	A_s	DR
1% M10	0.2	0.04	5
AD1	3.6	0.02	180
3% M10	0.7	0.1	7
3% M10	0.7	0.1	7
3% M10	0.7	0.1	7

Fig. 2. Measured optical parameter of multi-layer structure 1-3.

In our study, we compared the performance of our designed structures with that of a commercial polarizer. We made this comparison based on how well each structure balanced high absorbance with low loss of transmitted light.

The optimal design we selected is Structure 2, which consists of two LCP-M10 layers and one AD layer. The final structure is shown in Figure 3. In this composite film, the first LCP-M10 layer (referred to as M10-1) is placed directly above the AD1 layer. Its main role is to act as a shield, protecting the AD1 layer from ambient light. The second LCP-M10 layer (referred to as M10-2) has a higher Dichroic Ratio and is positioned so that it faces the incoming light from the source. When the light source is turned on, the light first passes through the M10-2 layer. This layer absorbs part of the light and reduces the intensity that reaches the AD1 layer. By doing so, the M10-2 layer helps maintain the alignment and stability of the AD1 layer, ensuring that the overall optical properties of the polarizer remain strong.

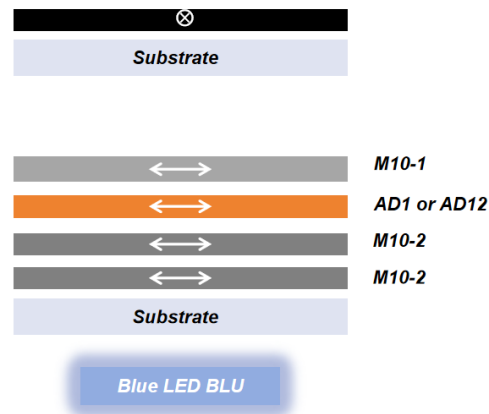


Fig. 3. Final design of multi-layer structure.

To test the photostability of the composite polarizer, we carried out an accelerated aging test. We exposed the composite polarizer to a polarized blue light source with an intensity of 0.24 mW/cm², which is double the usual required intensity. The test ran continuously for 1,800 hours. We measured the absorbance of the composite film in both the P state and the S state at the beginning of the test and again after 1,800 hours. We also measured the optical density at both times to check for any significant changes.

3. Results

The test results, shown in Figure 4, demonstrate that the multi-dichroic-layer composite polarizer maintains stable optical performance even under prolonged exposure to high-intensity blue light. At the beginning of the test and after 1,800 hours, the absorbance values in both the P-state and S-state remained nearly unchanged. Similarly, the optical density curves showed little to no variation, indicating that the composite polarizer retains its optical properties over time, even under accelerated aging conditions.

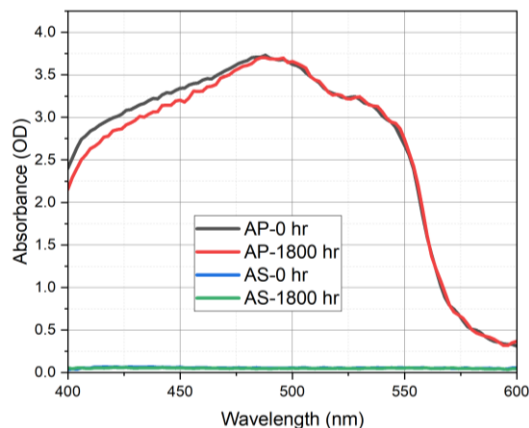


Fig. 4. Photostability test of multi-dichroic-layer composite polarizer.

These results confirm that adding LCP-M10 layers effectively slows the degradation of azo dye polarizers, allowing them to withstand prolonged blue light exposure without significant performance loss.

4. Discussion

In conclusion, the multi-dichroic-layer composite design proves to be an effective solution for enhancing the photostability of azo dye polarizers. By incorporating LCP-M10 layers, the structure reduces the impact of blue light and prevents degradation. The first LCP-M10 layer (M10-1) acts as a shield, blocking ambient light, while the second layer (M10-2) absorbs backlight-induced radiation, minimizing its effect on the AD1 layer. This layered approach maintains optical stability over extended use.

The composite polarizer's thin structure makes it suitable for modern LCD applications, balancing high absorbance with minimal transmission loss. The improved photostability ensures longer device lifespan and consistent display performance. Further studies can explore optimizing layer thickness, testing

under different environmental conditions, and evaluating large-scale production feasibility to enhance its practical application.

5. Acknowledgments

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6. References

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